FORERUNNER
RESEARCH INC

User Manual

GP-001/GP-002 CO_2 Gas Probe

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This guide is distributed by FORERUNNER RESEARCH INC ("Forerunner") for users of the GP-001 or GP-002 Gas Probe instruments in conjunction with the FRConnect-GP software. The GP housing and internal wiring is under warranty by Forerunner to be free from defects in workmanship and materials under normal use and service for thirty-six (**36**) months. The infrared gas analyzer sensor is covered by warranty against malfunction for twelve (**12**) months. This warranty shall not apply to any Forerunner products which have been subjected to misuse, modification, neglect, accidents of nature, or shipping damage. The GP membrane is not covered under warranty. This membrane will degrade over time and should be replaced after twelve (**12**) months. Membrane replacements are offered by Forerunner for purchase. Forerunner is not liable for special, indirect, incidental, or consequential damages. Forerunner's obligation under this warranty is limited to repairing or replacing (at Forerunner's discretion) defective products. The customer shall assume all costs of removing, reinstalling, and shipping defective products to Forerunner where applicable. Forerunner will return said products by surface carrier prepaid. This warranty is in lieu of all other warranties, expressed or implied.

DISCLAIMER: Please check the GP CO_2 Gas Probe Product page on the Forerunner website (http://www.forerunnerresearch.ca/GP.php) for the most up-to-date manual.

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GP001/GP002 and FRConnect-GP User Manual

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1 Introduction

This manual outlines the operation and features of the GP-001/GP-002 Carbon Dioxide (CO_2) Probes, as well as the included FRConnect-GP software package. Before providing power to the GP please ensure that you read the section on **Power Connectors** to avoid any damage to the sensor. We **strongly recommended** that all users read the complete manual before use.

The **Hardware** section explains the physical attributes of the GP and its accessories. The **FRConnect-GP User Interface** section explains the software that is used to communicate with the gas probes in order to record data and adjust logging parameters. The following **Logged Datafiles** section explains the structure and formatting of the datafiles recorded by FRConnect-GP, as well as what each field represents. A **Troubleshooting** section briefly covers some possible issues that may arise during normal operation of the software. For further information or assistance, please contact support@forerunnerresearch.ca.

2 Hardware

2.1 Overview

The GP sensor housing is constructed using a highly-durable acetal (Polyoxymethylene) housing, which has many advantages for field-use, such as high abrasion resistance and low water absorption. The housing is cylindrical with a diameter of 51 mm and a length of 107 mm (120 mm including the electrical connector).

Forerunner's NDIR CO_2 sensor is exposed to gases through a membrane covering the face of the GP housing. This membrane allows gas transport to the sensor, but does not allow any intrusion of liquid water. GP-001 sensors are guaranteed waterproof to 1 m of water column, whereas GP-002 sensors are waterproof to up to 3 m of water column. **The waterproofing of the sensor requires that users do not open the GP housing. A tamper-evident seal is placed on the GP housing to prevent intentional or accidental loosening of the cap. Any tampering with the cap will void the warranty on the GP and its components**.

2.2 Membrane Integrity

The GP membrane is critical to proper operation of the device. The membrane should always appear uniform in colour and free from visible defects. It is important to periodically check the membrane, as use in field conditions may cause it to tear or otherwise become defective, and the membrane will degrade naturally over time. Membranes should be replaced annually for best results, though the membrane life-cycle may be shortened by exposure to harsh conditions. **If the membrane appears to be compromised, it is critical that the GP not be submerged in water**. Contact Forerunner at 1-902-870-5220 or by email at support@forerunnerresearch.ca for additional information or to order membrane replacements.

When using the GP to monitor CO_2 concentrations in water columns deeper than 1 m, users should both slowly lower the sensor into the water and slowly extract the sensor after the monitoring period. Rapid submersion/extraction in deep water can cause rapid pressure changes in the sensor and can compromise the membrane seal, allowing water to leak into the sensor housing. A submersion/extraction timespan of 15 minutes in 3 m of water should be sufficient to avoid this problem.

2.3 CO_2 Measurement

The GP series of sensors measure gas concentration using non-dispersive infrared (NDIR) sensing, which correlates light source intensity to a specific gas concentration. The GP-001/GP-002 sensors offer a CO_2 concentration measurement accuracy of $\sim$1% of full scale, with a repeatability of 1% of reading. The GP CO_2 concentration readings are automatically corrected for changes in temperature, and can also be compensated for changes in atmospheric pressure using the ideal gas law correction:

$$C^* = C \times \frac{P_{ref}}{P_i}$$

where C is the raw concentration, P_{ref} is the reference pressure (101.35 kPa) and P_i is the pressure measured in the field (in kPa). This correction is incorporated into the FRConnect-GP software, but must be applied by the user for SE voltage concentration measurements. For applications where high accuracy is important, Forerunner recommends that users periodically check the calibration of their sensors by exposing them to known concentration standards. This is necessary as NDIR sensors can drift over time due to natural changes in the electrical and mechanical properties of the NDIR components.

2.4 Main Power & Data Cable

The GP-001/GP-002 ships with a standard 5 m long power and data cable (SSC) which plugs directly into the 12-pin socket on the GP housing. Figure 1 shows the SSC Power & Data Cable. Ensure that the notch on the SSC connector is aligned with the tab on the 12-pin GP socket, push to seat the connector on to the socket and hand tighten the connector.

Figure 1: SSC Main Power & Data Cable

Power is supplied to the GP via the two pin connector on the opposite end of the SSC. This connector also has a tab and notch type system to ensure that the user connects power with the correct polarity. The GP may be powered by supplying a regulated voltage to the sensor via data logger, battery or other power supply device. Please see the section entitled Power Connectors for more details.

Sensor data, including CO_2 concentration and sensor temperature measurements can be accessed by two methods. The first is by using the 3-pin Data connector on the SSC, combined with the Data connector cable. The FRConnect-GP software can then be used to read the data from the sensor (please see the section entitled FRConnect-GP User Interface for more information on using FRConnect-GP). Alternatively, the sensor output can be accessed using the single ended (SE) voltage outputs at the end of the SSC. Three wires provide signals corresponding to low-range CO_2 concentration (Purple), high-range CO_2 concentration[1] (Gray) and sensor temperature (Blue). All outputs are scaled from 0-5 V, but each voltage signal may correspond to a different range for concentration and temperature, depending on the sensor calibration. A example of typical values are shown in Table 1. Please note that the scaling factors will be affected by calibration ranges and the user should be aware of their sensor specific calibration.

Parameter	Voltage Range	Actual Range
Low-range CO_2 Concentration	0-5 V	0→5000 ppm
High-range CO_2 Concentration	0-5 V	0→20000 ppm
Temperature	0-5 V	-20°C→50°C

Table 1: Scaling for single ended voltage outputs on the GP 001/002 sensors.

The equations below show an example calculation of CO_2 concentration from an assumed single ended voltage reading (SEV) of 2 V:

$$\text{SEV}=2\text{ V}$$
$$2\text{ V}/5\text{ V}=0.4$$
$$0.4*5000\text{ ppm} = 2000\text{ ppm}$$

Please note that unless a specific temperature calibration was requested, the range for temperature is -20°C to 50°C. Finally, the optional 10 m cable (SLC) has the same configuration and outputs as the SSC.

[1] High-range calibration values available only with optional dual calibration. With single range calibrated devices, Gray SE wire is auxiliary (e.g. CO_2 alarm, CO_2 concentration deviation, etc).

2.5 Power Connectors

The power supply cable included with the GP 001/002 sensors allows for powering the sensor using a DC power supply (DC+).

Figure 2: DC+ Power Cable

Figure 2 shows the DC+ external power cable. The cable includes a 2-pin connector for attachment to the SSC/SLC cables. The opposite end of the cable has stripped wire ends, to allow for connection to any DC power supply. The **black wire** should be attached to the ground terminal of the DC power device, and the **red wire** should be attached to the positive terminal. The GP can operate on DC power ranging from 5-24 V, with 12 V being the standard voltage used during calibration and testing. **Exceeding 24 V will damage the GP**, please ensure that the voltage is regulated correctly before connecting the power supply to the GP. The power consumption will vary slightly depending upon the supplied voltage. At the recommended voltage of 12 V, the average draw is ∼30 mA with a peak of <100 mA, giving an average power draw of ∼0.36 W.

2.6 Data Cable

Communication between FRConnect-GP and a GP-001/GP-002 uses the RS-232 Serial protocol. The following components may be used to facilitate this interface.

- GP Data/Power Cable (Fig. 1) - (*Included*) Used to power a GP-001/GP-002 as well as provide an RS-232 interface.
- Serial Extension Cable (Fig. 3a)- (*Included*) Connects the GP Data cable to a USB-Serial converter.
- USB-Serial Converter (Fig. 3b) - (*Optional*) Used to create a virtual comport, allowing the GP Data cable to be connected to a computer through a USB port.

(a) Serial Extension Cable

(b) USB-Serial Converter

Figure 3: Data Cables

3 FRConnect-GP User Interface

3.1 Setup and Connection

FRConnect-GP requires no installation on the part of the user. Simply download the file "FRConnect-GP.zip" from the GP CO_2 Gas Probe product page on the Forerunner website (http://www.forerunnerresearch.ca/GP.php) and save to a suitable directory on the PC in question; then, unzip[2] the file (which contains one folder titled "FRConnect-GP"). None of the files in this folder should be removed or changed in any way. If this occurs, simply remove the entire folder from your PC and re-extract from the zip file to recreate the folder.

The program executable is labeled "FRConnect-GP.exe"[3], and double clicking this icon or a Desktop Shortcut will launch the program. It is recommended that you connect the USB data cable to your computer **prior to launching FRConnect-GP**; however you may also refresh the program from the Options menu. The port on which the GP is connected will likely be the only choice available (`Options`⇒`ComPort`⇒`COM#`), however you may have to refer to the device manager if several serial port devices are connected to the computer. Once the port is selected, a connection to the gas probe will be created.

3.2 Using the Interface

Figure 4 shows the FRConnect-GP interface. The interface has three main areas: the logging options; the current reading and start/stop controls; and the plotting area. The top section shows the currently selected datafile/frequency and the specified external pressure value (used to correct gas concentrations). These settings can be modified via the change buttons situated on the right, or from the menubar.

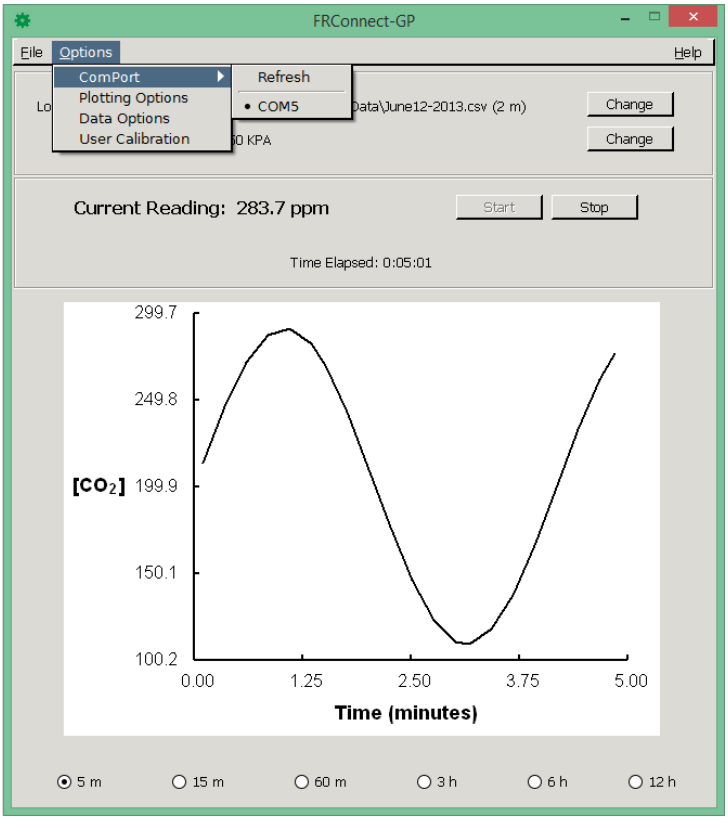

Figure 4: FRConnect-GP Main Window

The middle section shows the current CO_2 concentration reading, and allows the user to start and stop logging/plotting. It also shows how long the current logging session has been running. Clicking the `Start` button will enable FRConnect-GP to start collecting measurements from a connected GP-001 or GP-002, and to both plot and log this data. Note that the plot will show every individual measurement, while the datafile will contain averages over an interval specified by the user. Once a session has been started, clicking the `Stop` button will stop FRConnect-GP from recording measurements from the gas probe. The plotted values will remain until the `Start` button is used again, at which point the plot will be reset.

[2] If your computer lacks decompression software, 7zip is a suitable free utility for handing archive files
[3] Your computer may be set to hide the .exe extension

The bottom section contains a plot of recent concentrations over the chosen time interval. This interval defaults to 15 minutes, but can be changed using the radio buttons at the bottom. If the collected data exceeds this interval, then only the most recent points will be shown. There are several secondary plotting options available in `Options⇒Plotting Options`, including the ability to toggle between an automatic and fixed scale for the Y-axis.

To start collecting data, first choose a location to save logged data by clicking the `Change` button across from the "Logging to:" line, or by choosing `File⇒New Log File`. Select or create a CSV file using the Open File window. Please note that if the selected file already exists, new data will be appended at the end of the file with a new header line. Once you have chosen a save file the Data Options window will appear. Choose the desired formatting options and which fields to log from the Data Options window as shown in Figure 5.

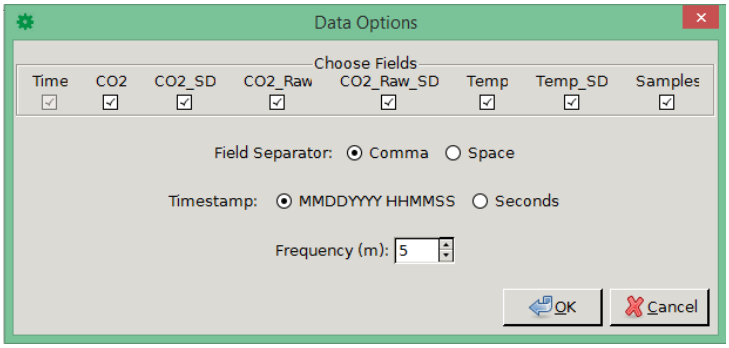

Figure 5: FRConnect-GP Data Options

For GP units equipped with the optional dual range calibration, the range can be toggled from the `Options⇒Plotting Options` window as shown in Figure 6. To plot data using the high calibration range check the box next to "Use High-Concentration Calibration?"

Click the `Start` button to begin logging data. In addition to being stored in the selected file, a plot of the CO_2 concentration measurements is shown in the FRConnect-GP window.

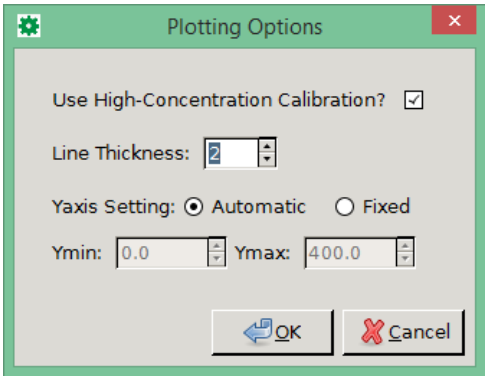

Figure 6: FRConnect-GP Plotting Options

4 Logged Datafiles

The measurement data file is formatted as a comma separated values file (.csv) by default, allowing for easy importing into spreadsheet or plotting software.

	A	B	C	D	E	F	G	H	I	J	K	L
1	Timestamp	CO2_Low	CO2_Low_SD	CO2_High	CO2_High_SD	CO2_Low_Raw	CO2_Low_Raw_SD	CO2_High_Raw	CO2_High_Raw_SD	Temp	Temp_SD	Samples
2	6/5/2014 8:23	602.7	1.757	528.3	1.838	602.7	1.757	528.3	1.838	28.9	0.007	8
3	6/5/2014 8:24	601.1	1.982	526.6	2.064	601.1	1.982	526.6	2.064	28.9	0.007	8
4	6/5/2014 8:25	602.4	2.573	528	2.679	602.4	2.573	528	2.679	28.9	0.011	8
5	6/5/2014 8:26	603.1	2.28	528.7	2.376	603.1	2.28	528.7	2.376	28.9	0.012	8
6	6/5/2014 8:27	606.4	2.113	532.1	2.206	606.4	2.113	532.1	2.206	28.9	0.011	8
7	6/5/2014 8:28	606	0.72	531.7	0.752	606	0.72	531.7	0.752	28.9	0.012	8
8	6/5/2014 8:29	606.6	1.802	532.3	1.882	606.6	1.802	532.3	1.882	28.9	0.01	8
9	6/5/2014 8:30	605.7	2.031	531.4	2.116	605.7	2.031	531.4	2.116	29	0.013	8
10	6/5/2014 8:31	608.8	1.329	534.6	1.386	608.8	1.329	534.6	1.386	29	0.011	8
11	6/5/2014 8:32	609.8	1.98	535.6	2.069	609.8	1.98	535.6	2.069	29	0.012	8
12	6/5/2014 8:33	610.3	1.043	536.2	1.09	610.3	1.043	536.2	1.09	29	0.013	8
13	6/5/2014 8:34	610.7	2.276	536.6	2.378	610.7	2.276	536.6	2.378	29	0.01	8
14	6/5/2014 8:35	610.4	1.636	536.2	1.71	610.4	1.636	536.2	1.71	29	0.011	8

Figure 7: Sample FRConnect-GP data file

Each of the possible data fields in the output file are listed below, with a brief description of what that value represents.

Timestamp	The timestamp for the line of data. The default format is "MM/DD/YYYY HH:MM:SS", with the option of changing to seconds since start of session.
CO2_Low	The average CO_2 concentration over the interval using the low-range calibration (ppm).
CO2_Low_SD	The standard deviation of CO2_Low during the interval (ppm).
CO2_High	The average CO_2 concentration over the interval using the high-range calibration (ppm).
CO2_High_SD	The standard deviation of CO2_High during the interval (ppm).
CO2_Low_Raw	The average CO_2 concentration over the interval using the low-range calibration ignoring user corrections (ppm).
CO2_Low_Raw_SD	The standard deviation of CO2_Low_Raw during the interval (ppm).
CO2_High_Raw	The average CO_2 concentration over the interval using the high-range calibration ignoring user corrections (ppm).
CO2_High_Raw_SD	The standard deviation of CO2_High_Raw during the interval (ppm).
Temp	The average temperature over the interval (°C).
Temp_SD	The standard deviation of temperatures measured during the interval (°C).
Samples	The number of samples that occurred during the interval.

5 Troubleshooting

This section provides a few example problems that may occur during use, and the appropriate action that should be taken to resolve the issue. For these issues as well as any others that arise, please contact Forerunner Research Inc. at 1-902-870-5220, or by emailing us at support@forerunnerresearch.ca.

- ***The GP does not seem to be outputting serial data (using FRConnect-GP) or SE voltages***

  Please ensure that the power supplied to the GP is between 5 and 24 VDC.

- ***FRConnect-GP does not show or log any data.***

  Ensure that the gas probe is connected to power and that a session has been started (via the `Start` button in FRConnect-GP). Check that the correct ComPort has been selected under `Options`⇒`ComPort`. If the problem persists, exit FRConnect-GP, disconnect and then reconnect the USB data cable, then re-launch FRConnect-GP.

- ***No ComPorts show up under `Options`⇒`ComPort`***

  Ensure that the gas probe is connected to power. Open the device manager from the Control Panel in Windows and reconnect the USB data cable. If no connections show up under `Ports (Com & LPT)`, please contact Forerunner for further instruction.

- ***The GP socket/cable is oxidizing/discolouring when used in water***

  In environments which have higher than normal levels of salt or other ions, the GP socket and/or cable may oxidize or discolour. This will not affect the measurement performance, but will shorten the lifetime of the sensor. In these types of environments we recommend attaching the cable to the GP probe and then lightly coating the metal components with silicone grease (i.e. high-vacuum grease). Coating with silicone grease is also advisable in waterlogged soils.

- ***S.E. voltage outputs vary with power supply type/voltage***

  The S.E. voltage wires output 0 V to 5 V signals that correspond to the current CO_2 and temperature readings in the sensor. These outputs can be monitored as an alternative to receiving digital data. If the GP is powered independently of the device which is logging the S.E. voltages, then the S.E. voltage may change with varying power supplies even if the gas concentration or temperature has not changed. It is critical that the device which is logging the S.E. voltages and that providing the power for the GP have the same ground. For example if using a commercially available data logger to log the S.E. voltage, also use the 12 V power supply port that exists on the data logger.

- ***GP readings are abnormally noisy***

  The GP sensor requires a stable power supply with minimal noise in order to achieve the lowest possible noise on concentration and temperature measurements. When using the GP, ensure that the power supply is of high quality or that the power supply variation is buffered with an in-line battery or other power smoothing device. If you are unsure about your power supply setup please contact Forerunner.

- ***GP readings are off from my laboratory standard***

  Forerunner makes all efforts to ensure accurate calibration, including periodic checks against NIST traceable standards, however calibrations may vary from individual laboratory standards. There are several reasons for this, including long term sensor drift, changes in atmospheric pressure (sensors are calibrated at sea-level) and variation in gas supplier analysis techniques. We highly recommend that users concerned with comparing GP results with other laboratory and field instrumentation re-calibrate GP sensors using the same standards, and/or cross calibrate all instruments.

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